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Impact of Soil Inter-space Bulk Density and Moisture Content on Vitamin A Content of Stored Oranges in Passive Evaporative Cooling Structures

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Abstract - A study was conducted on the impact of soil inter-space bulk density and moisture content on the vitamin A content of stored oranges in passive evaporative cooling structures. Two sets of four different types of passive evaporative cooling structures made of two different materials, clay and aluminium were constructed. One set consists of four separate cooling chambers. Two cooling chambers were made with aluminium container (round and rectangular shapes) and the other two were made of clay container (round and rectangular). These four containers were separately inserted inside bigger clay pots and lateritic walls inter- spaced with clay soil of 5 cm (to form tin-in-pot, pot-in-pot, tin-in-wall and wall-in wall) with the outside structure wrapped with jute sack. The other set followed the same pattern with interspacing of 10 cm. The two sets (5 cm and 10 cm interspaced soil) were constantly wetted with salt solution (sodium chloride, NaCl)) at intervals of between 2 to 4 hours depending on the rate of evaporation to keep the soil in moist condition. In addition, the control has no fans and the inner cooling chambers were not lined with polyethylene nylon while the other two sets have fans and their inner cooling chambers lined with polyethylene nylon Freshly harvested oranges were used for the experiment and the inter-space soil bulk density, soil moisture content and vitamin A content of stored oranges were determined at interval of three days for a period of three weeks. The interspace soil bulk density values of 0.98 g/cm^3, 1.6 g/cm^3, 0.91 g/cm^3, 0.98 g/cm^3, 0.99 g/cm^3, 0.97 g/cm^3 and 0.92 g/cm^3 with the soil moisture contents values of 78.4%, 81.58%, 82.56%, 79.12%, 79.68%, 79.74% and 79.74% were recorded for the 5 cm structures. Also the interspace soil bulk density values of 1.42 g/cm^3, 1.21 g/cm^3, 1.34 g/cm^3, 1.00 g/cm^3, 0.98 g/cm^3, 0.98 g/cm^3 and 0.97 g/cm^3 with the soil moisture contents values of 78.73%, 79.17%, 78.18%, 78.34%, 82.54%, 81.79% and 81.36% were recorded for the 10 cm structures.

Keywords - Bulk Density, Vitamin A, Soil, Cooling, Evaporation.

1. INTRODUCTION

Fruits and vegetables are of good importance to human health. They contain antioxidants, minerals and phytochemicals in their correct combination that help keep the blood sugar in balance, create energy in the body and build up the immune system (Ray, 2011). An orange, specifically sweet orange (*Citrus sinensis*), is the most commonly grown fruit in the world (Morton, 1987). Common oranges (also called "white", "round or "blond" oranges) make up two-thirds of all oranges grown and are used primarily to produce juice (Kimball and Dan, 1999). The abundance of antioxidants, vitamins, fibre and phytonutrients in orange foods are good for the skin, eyes and heart, and they may also decrease the risk of cancer and lower high blood pressure. In recent research studies, the healing properties of oranges have been associated with a wide variety of phytonutrient compounds. An orange has over 170 different phytonutrients and more than 60 flavonoids, many of which have been shown to have anti-inflammatory, anti-tumour and blood clot inhibiting properties, as well as strong antioxidant effects. (Yuan *et al.*, 2003; Stange *et al.*, 1993; Wood, 1988; Rapisarda *et al.*, 1999; Pattison *et al.*, 2004 and Cho *et al.*, 2004).

Vitamin A is present in fruits and can be stored by the body in large quantities. Oyenuga (1968) reported values of Vitamin A as 200 IU for guava, 190 IU for sweet orange, 420 IU for tangerine and 590 IU for water melon. Vitamin A deficiency results in xerophtalmia-characterized by dry corneal membranes. Its deficiency also brings about a malfunction in the visual purple and the consequent night blindness. Vitamin A is important for night vision, as an antioxidant can neutralize the

damaging free radicals in the body, and is crucial in the health of the immune system.

Oranges can be kept at room temperature for a week or so but keep well for up to two weeks in the fruit/vegetable compartment of the home refrigerator. Oranges can be stored for up to 2 weeks under optimum storage conditions. Ultimate storage life depends on cultivar, maturity, pre-harvest conditions and postharvest handling. Orange must be kept loose in the fruit container and place in cool area away from excessive moisture as they tend to get mould infection early (Whiteman, 1957).

The need to pre-cool fruits and vegetables is well accepted, and is especially important for high-value and for highly perishable produce (Paul, 1987). Benefits include longer postharvest life, better maintenance of quality, lower losses due to weight loss, decay and water loss. Some common pre-cooling methods include room cooling, hydro-cooling (immersion or shower type), radiant cooling and night air ventilation among others (Gast and Flores, 1991; Mitchell, 1992).

Cooling involves heat transfer from fresh produce to a medium such as cold water, ice or cold air. Heat transfer processes include conduction, convection, radiation and evaporation. Evaporative cooling is a low cost method of refrigeration that uses water-soaked media in “swamp coolers” requiring only the use of electric fan (Thompson *et al.*, 2003) or requiring no electricity in passive systems that involve the use of some kind of fibre, rice hulls, straw or charcoal filled walls (Anyanwu, 2004; Acedo, 1997). Evaporative coolers do not use compressors, condensers, chillers or heavily insulated piping. Thus, the cost of acquisition and operation is a fraction of that for mechanical system.

Most evaporative cooling structures are made of two walls separated by an inter-space which is normally filled with river bed sand (Babarinsa *et al.*, 1988; NSPRI, 1990) and the porosity of which affects the degree of cooling obtainable. Consequently, it is expected that moisture losses of stored produce can be reduced and the shelf life can be prolonged.

A variety of methods have been employed to determine bulk density of soil (Avery and Bascombe, 1974; Smith and Mullins, 2001; Timm *et al.*, 2005). Bulk density is the dry mass of soil solids per unit volume of soils and the bulk densities of mineral soils are usually in the range of 1.1 to 1.7g/cm^3. Bulk density varies depending on factors such as texture, aggregation, organic matter, compaction, soil management practices and soil horizon (Brady and Weil, 2001). Soil water-holding capacity is determined largely by the interaction of soil texture, bulk density, pore space and aggregation. Bulk density reflects the soil’s ability to function for water movement and soil aeration. The effect of compaction on soil bulk density was higher when soil was compacted under wet condition. High bulk density is an indicator of low soil porosity and soil compaction. It causes poor movement of air and water through the soil (Lipiec and Hatano, 2003).

Clay is the finest soil particle size class. Individual particles are finer than 0.002mm. They feel extremely smooth or powdery when dry and become plastic and sticky when wet. The rate of cooling depends on the air temperature and soil wetness. Clay soil generally absorbs a relatively large amount of water and their small pores retain it (Fanning and Fanning, 1989). This study aims at studying the impact of soil inter-space bulk density and moisture contents on vitamin A content of stored oranges in passive evaporative cooling structures.

2. Materials and Methods

The samples of oranges used in this study were sourced from Bosso Market in Minna, Niger State, Nigeria. The fresh oranges were stored inside the two sets of four different types of passive evaporative cooling structures for a period of 21 days. Thirty samples of fresh oranges were stored in each structure.

3. Nutritional Parameters

Nutritional Analysis for vitamin A of the orange samples was carried out in the Central Laboratory of National Cereals Research Institute, Badeggi, Nigeria using AOAC (1995) methods of analysis. . All measurements were performed in triplicates and results were given as mean ± standard error (SE).

4. Determination of Soil Bulk Density

The bulk density was determined by core method in line with AOAC (1979).

5. Preparation of Salt Solution

About 15000 parts/million (ppm) solution of sodium chloride (NaCl) was prepared by dissolving 225g of NaCl in 15 litres of water at room temperature and 450g of NaCl in 30 litres of water at room temperature for keeping the four structures in moist condition in the 5 cm and 10 cm soil inter-space respectively.

6. Results and Discussion

The vitamin A values of stored oranges in different structures for a period of 21 days are presented in Table 1 while the bulk densities and moisture contents at different soil interspaces are presented in Tables 2 and 3 respectively. From Table 1, it can be seen that higher values of vitamin A were recorded in the tin-in-pot structure with 10 cm soil inter-space compared with the 5 cm soil inter-space on the 1st, 5th, 11th, 15th, 18th and 21st days of storage. This was as a result of higher moisture contents (Table 3) in the soil that occurred as a result of soil cracking that allows rapid transport of water to the soil (Kissel *et al.*, 1974; Harris *et al.*, 1994; Bronsnwijk *et al.*, 1995; Kelly and Pomes, 1998). However, lower moisture contents were recorded on the 5th, 8th and 11th days in the tin-in-pot structures with 10 cm inter-space which was as a result of large surface area which allowed for faster rate of evaporation compared with tin-in-pot

structures with 5 cm soil inter-space. It can also be deduced from Table 1 that lower values of vitamin A occurred in the pot-in-pot structures with 10 cm soil inter-space on the 1st, 5th, 11th and the 21st days of storage compared with pot-in-pot structures with 5 cm soil inter-space. This was as a result of higher bulk density values (Table 2) which is an indication of low soil porosity that eventually results to poor movement of air and water through the soil (Hakansson *et al*., 1998; Arvidson, 1987; Lipiec and Hatano, 2003).The poor movement of air and water through the soil affects the nutritional contents of stored oranges in the structures.

Also from Table 1, higher values of vitamin A were recorded in the tin-in-pot structure with 10 cm soil inter-space compared with the 5 cm soil inter-space on the 1st, 5th, 8th, 18th and 21st days of storage. This was as a result of higher moisture contents (Table 3) in the soil that occurred as a result of soil cracking that allows rapid transport of water to the soil (Kissel *et al*., 1974; Harris *et al*., 1994; Bronsnwijk *et al*., 1995; Kelly and Pomes, 1998). However, lower moisture contents were recorded on the 5th and 8th days in the tin-in-pot structures with 10 cm inter-space which was as a result of large surface area which allowed for faster rate of evaporation compared with tin-in-pot structures with 5 cm soil inter-space. It can also be deduced from Table 1 that lower values of vitamin A occurred in the pot-in-pot structures with 10 cm soil inter-space on the 1st, 8th, 15th and the 18th days of storage compared with pot-in-pot structures with 5 cm soil inter-space. This was as a result of higher bulk density values (Table 2) which is an indication of low soil porosity that eventually results to poor movement of air and water through the soil (Lipiec and Hatano, 2003). The poor movement of air and water through the soil affects the nutritional contents of stored oranges in the structures. Hamza and Anderson also attributed soil compactions (which occur as a result of high bulk density) to reduction in soil porosity which causes decrease in soil aeration and hydraulic conductivity as reported by Al-Adawi and Reeder (1996).

Table (1) Changes in Vitamin A (IU) Contents of Stored Oranges in Different Evaporative Coolers at Different Interspace

Storage	Interspace	Changes in Vitamin C Contents in Storage						
Type		day 1	day 5	day 8	day 11	day 15	day 18	day 21
Tin-in-pot	5 cm	11.76	10.98	12.14	16.74	18.12	12.54	11.30
Pot-in-pot		14.62	12.62	11.42	18.63	14.56	14.76	12.52
Tin-in-wall		11.56	12.32	11.12	16.98	18.14	14.54	12.30
Wall-in-wall		14.76	13.14	12.32	16.94	16.52	16.72	11.54
Tin-in-pot	10 cm	12.32	11.12	11.74	17.04	18.14	16.66	11.34
Pot-in-pot		13.88	12.40	11.52	18.03	14.66	14.98	12.40
Tin-in-wall		12.21	12.72	11.14	16.88	18.10	14.64	12.32
Wall-in-wall		13.22	13.18	12.21	17.06	15.89	16.22	11.54

Table (2) Changes in Bulk Densities of Soil Interspace in Different Evaporative Cooling Structures of Stored Oranges.

Storage	Interspace	Changes in Bulk Densities						
Type		day 1	day 5	day 8	day 11	day 15	day 18	day 21
Tin-in-pot	5 cm	0.98	1.16	0.91	0.98	0.99	0.97	0.92
Pot-in-pot	5 cm	0.98	1.16	0.91	0.98	0.99	0.97	0.92
Tin-in-wall	5 cm	0.98	1.16	0.91	0.98	0.99	0.97	0.92
Wall-in-wall	5 cm	0.98	1.16	0.91	0.98	0.99	0.97	0.92
Tin-in-pot	10 cm	1.42	1.21	1.34	1.00	0.98	0.98	0.97
Pot-in-pot	10 cm	1.42	1.21	1.34	1.00	0.98	0.98	0.97
Tin-in-wall	10 cm	1.42	1.21	1.34	1.00	0.98	0.98	0.97
Wall-in-wall	10 cm	1.42	1.21	1.34	1.00	0.98	0.98	0.97

Table (3) Changes in Moisture Contents of Soil Interspace in Different Evaporative Cooling Structures of Stored Oranges.

Storage	Interspace	Changes in Moisture Contents						
Type		day 1	day 5	day 8	day 11	day 15	day 18	day 21
Tin-in-pot	5 cm	78.4	81.58	82.56	79.12	79.68	79.74	79.74
Pot-in-pot	5 cm	78.4	81.58	82.56	79.12	79.68	79.74	79.74
Tin-in-wall	5 cm	78.4	81.58	82.56	79.12	79.68	79.74	79.74
Wall-in-wall	5 cm	78.4	81.58	82.56	79.12	79.68	79.74	79.74
Tin-in-pot	10 cm	78.73	79.17	78.18	78.34	82.54	81.79	81.36
Pot-in-pot	10 cm	78.73	79.17	78.18	78.34	82.54	81.79	81.36
Tin-in-wall	10 cm	78.73	79.17	78.18	78.34	82.54	81.79	81.36
Wall-in-wall	10 cm	78.73	79.17	78.18	78.34	82.54	81.79	81.36

7. Conclusions

Higher values of vitamin A contents of stored oranges were observed in most cases in 10 cm soil inter-space structures as a result of cracking which allowed rapid infiltration. However, the use of tin-in-pot and tin-in-wall structures that were made of lighter materials like aluminium is recommended to minimize the effect of soil compaction and reduce bulk density of the soil to allow for proper water movement and soil aeration.

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